

Aluminum Amalgam¹

Al-Hg

[11146-30-8] · Al · Aluminum Amalgam · (MW 26.98)

(reducing agent for many functional groups,¹ effects reductive dimerization of unsaturated compounds, can cleave carbon-element and element-element bonds.)

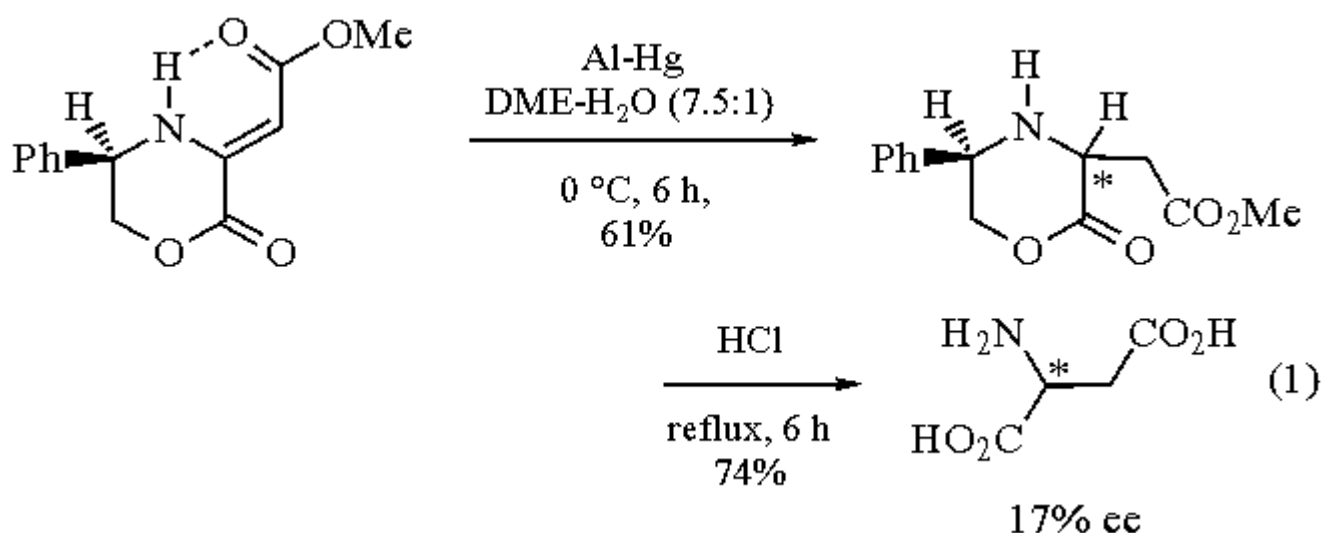
Physical Data: shiny solid.

Preparative Methods: **Aluminum** turnings (oil-free) are etched with dilute **Sodium Hydroxide** to a point of strong hydrogen evolution and the solution is decanted. The metal is washed once with water so that it retains some alkali, then treated with 0.5% **Mercury(II) Chloride** solution for 1-2 min, and the entire procedure is repeated. The shiny amalgamated metal is washed rapidly in sequence with water, ethanol, and ether and used at once.² Aluminum amalgam (1) reacts vigorously with water with liberation of hydrogen in the amount equivalent to the amount of aluminum present and can be used to dry organic solvents (ether, ethanol).^{2a} Aluminum amalgam can be also prepared from aluminum foil, which is cut into strips ~10 cm × 1 cm and immersed, all at once, into a 2% aqueous solution of HgCl₂ for 15 s. The strips are rinsed with absolute alcohol and then with ether and cut immediately with scissors into pieces ~1 cm square, directly into the reaction vessel.^{2b} Before immersion, each strip may be rolled into a cylinder ~1 cm in diameter. Each cylinder is amalgamated, rinsed successively with ethanol and ether and then placed in the reaction vessel.^{2c}

Handling, Storage, and Precautions: moisture-sensitive. Precautions should be taken as it readily reacts with water with hydrogen evolution. Can be stored under dry ether. Toxic.

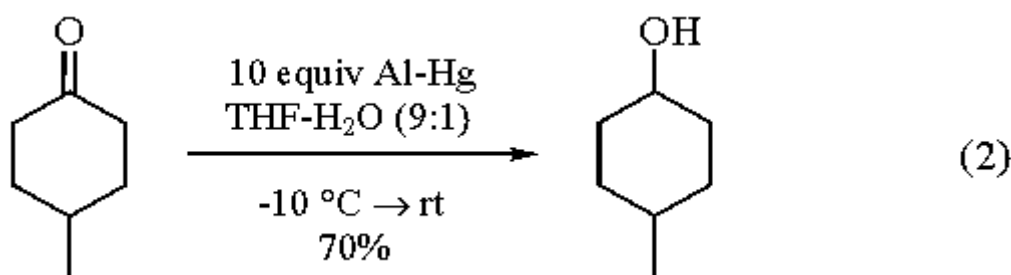
C=C Bond Reduction.

Alkenic substrates are transformed into saturated compounds upon reaction with Al-Hg. Substrates with carbon-carbon double bonds activated by electron-withdrawing substituents are most easily reduced.³ The reaction may proceed with asymmetric induction and high chemoselectivity, leaving other functionalities unchanged (eq 1).⁴ Reduction of 1,3-dienes^{5a} and α -nitroalkenes^{5b} results in 1,4-addition of hydrogen to the π -system. Aluminum amalgam can also promote reductive dimerization of α,β -unsaturated acid esters.^{6a,b}



C=O Bond Reduction.

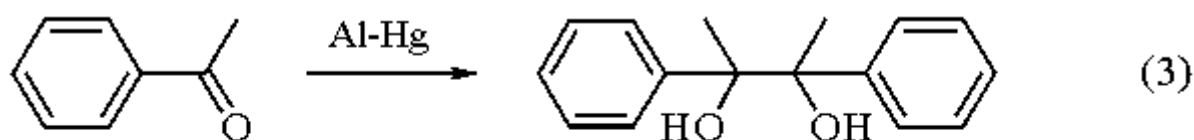
Cycloalkanones and aldehydes are reduced to the corresponding alcohols (eq 2). Acyclic ketones remain almost inert.⁷



In spite of the ability of carboxylic acid esters to be reduced to alcohols,⁸ in oxosuccinic acid esters only the ketone carbonyl group is reduced.⁹

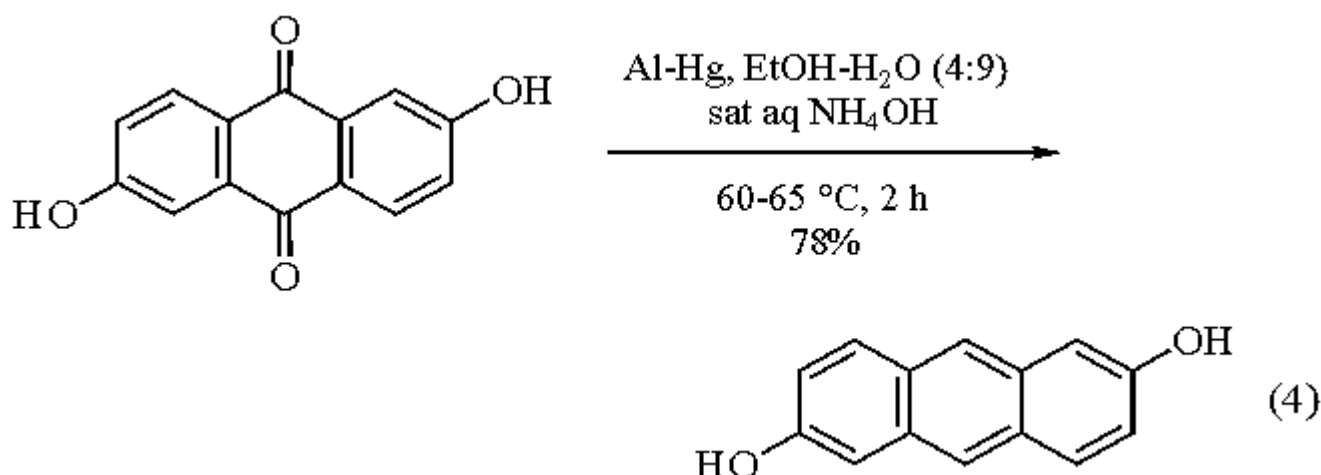
Ultrasound-promoted reduction of the C=O group of *N*-substituted phthalimides leads to hydroxylactams. The ultrasonic irradiation provides rapid fragmentation of the amalgam, giving a reactive dispersion and accelerates the reaction owing to the increase of mass transport between the solution and the Al/Hg surface where reduction occurs. The reaction is highly sensitive to substrate structure and *N*-benzylglutarimide and *N*-benzylsuccinimide are not reduced.¹⁰

Reductive dimerization of carbonyl compounds to pinacols does not always effectively compete with reduction to alcohols, but in certain cases it becomes the main process (eq 3).^{7,11} Factors which determine reduction-dimerization ratios include steric inhibition, torsion strain, and angle strain.⁷



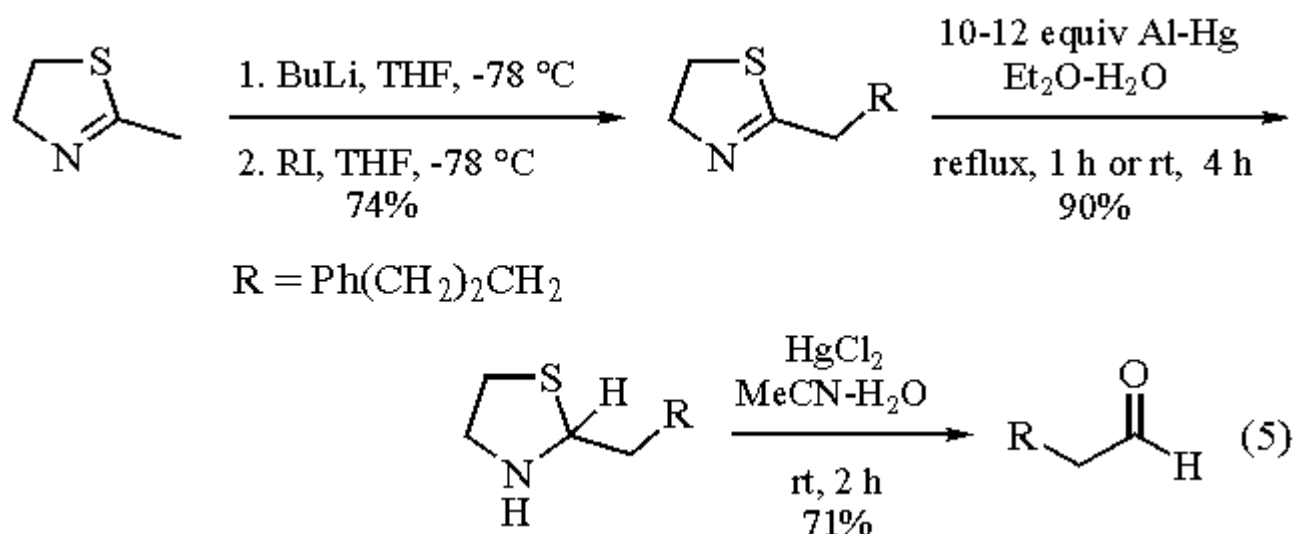
CH₂Cl₂, reflux, 1-4 h, 21-38%
 C₆H₆-EtOH (1:1), reflux, 4 h, 95%
 THF-H₂O (9:1), -10 °C → rt, 94%

A special case of reduction involves removal of the carbonyl oxygens from anthraquinones^{12a,b} and related compounds¹³ with rearomatization (eq 4).^{12b}



C=N Bond Reduction.

Aluminum amalgam reduces Schiff bases to the corresponding amines.¹⁴ Among these reactions of great importance is the reduction of Δ^2 -thiazolines to thiazolidines,¹⁵⁻¹⁷ widely used in the synthesis of aldehydes (eq 5),¹⁵ β -hydroxy aldehydes, and homoallylic alcohols.¹⁶

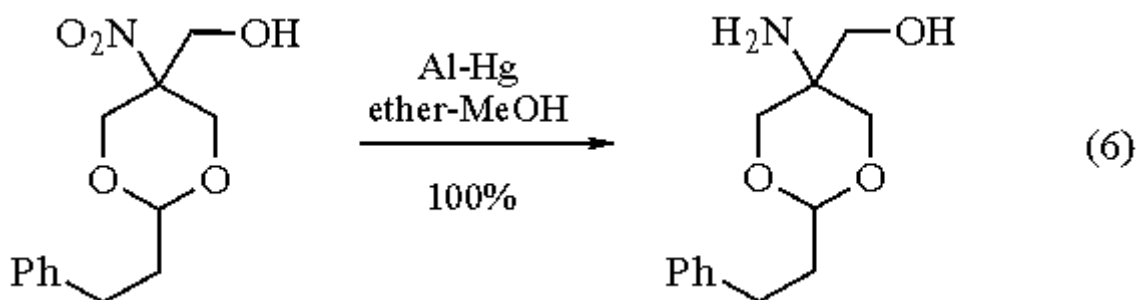


Aluminum amalgam also induces reductive dimerization of Schiff bases^{14a,18} to produce 1,2-diamines. This process has been used in macrocyclic ring closure.^{18a} In respect to reductive dimerization of Δ^1 -pyrrolines, aluminum amalgam is much more effective than **Zinc** in aqueous

NH₄Cl.^{18b} Similar to Schiff bases, oximes are also readily reduced to corresponding amines,¹⁹ while reduction of hydrazides provides hydrazines.²⁰

NO₂ and N₃ Group Reduction.

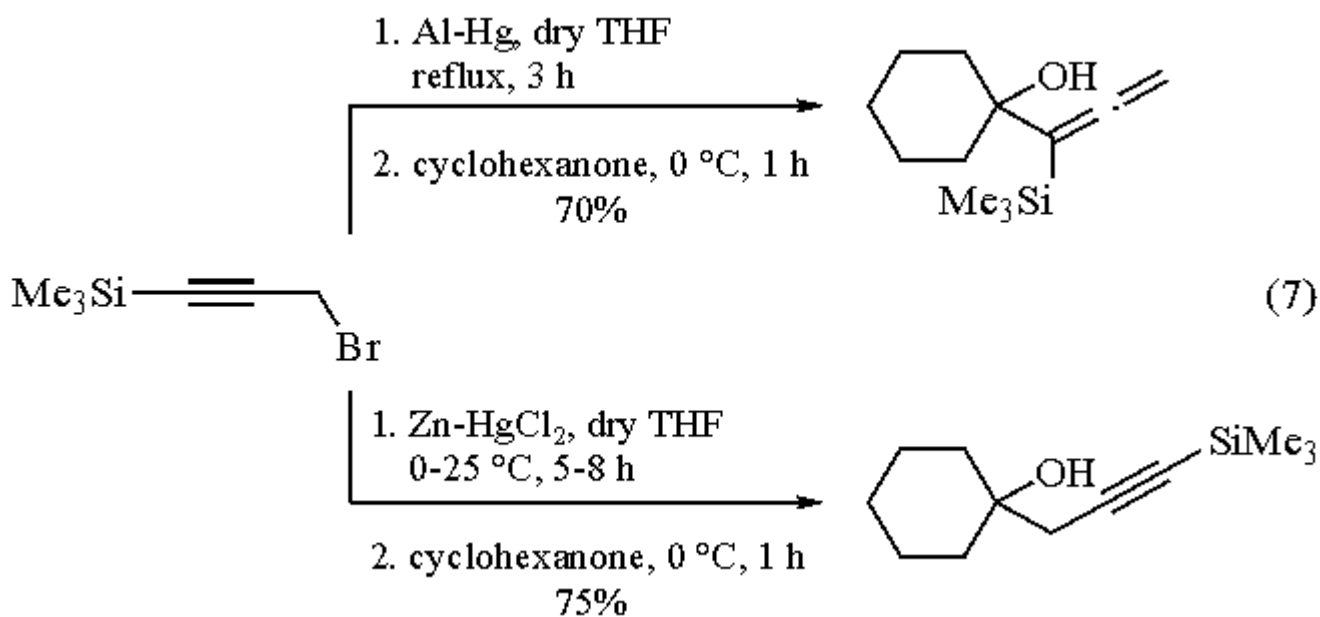
Aluminum amalgam reduction is an excellent method for deoxygenation of aliphatic and aromatic nitro groups to produce amines²¹ (eq 6).^{21d} Nitro alkenes can be chemoselectively reduced, retaining the C=C bond.^{21a} In moist ether the reduction can be stopped at the stage of hydroxylamine formation.²²



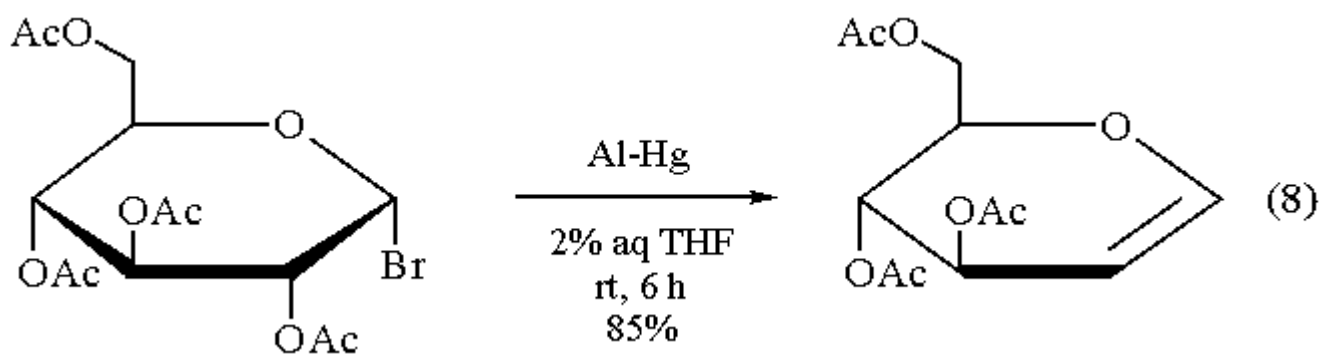
Organic azides are also readily reduced to the corresponding amines. The procedure has been used in a general synthesis of α,β -unsaturated α -amino acids.²³

Reactions of Carbon-Halogen Bonds.

Organic halides exhibit diverse behavior in reactions with Al-Hg. Thus a trichloromethyl group has been reduced to a dichloromethyl group.²⁴ At the same time, Al inserts into the C-Br bond of silylated propargyl bromide affording the allenylaluminum reagent, whereas only direct metalation without rearrangement has been observed in metalation with **Zinc Amalgam** (eq 7).²⁵

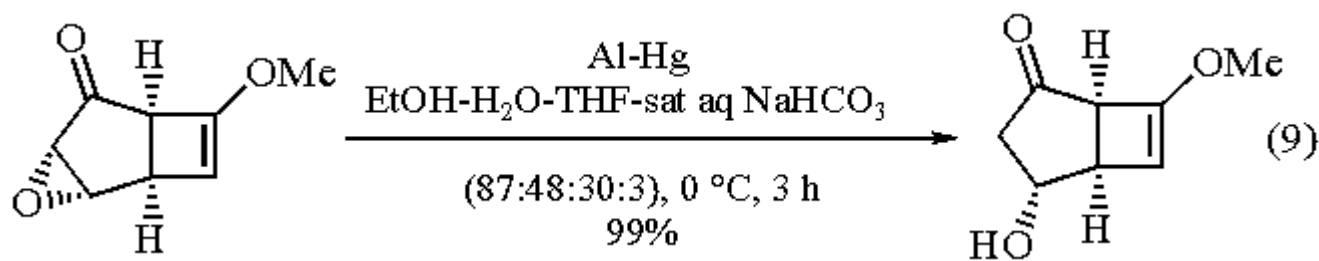


Mild reductive deacetoxybromination of glycosyl bromides offers an approach to glucals bearing acid-sensitive substituents (eq 8).²⁶



C-O Bond Cleavage.

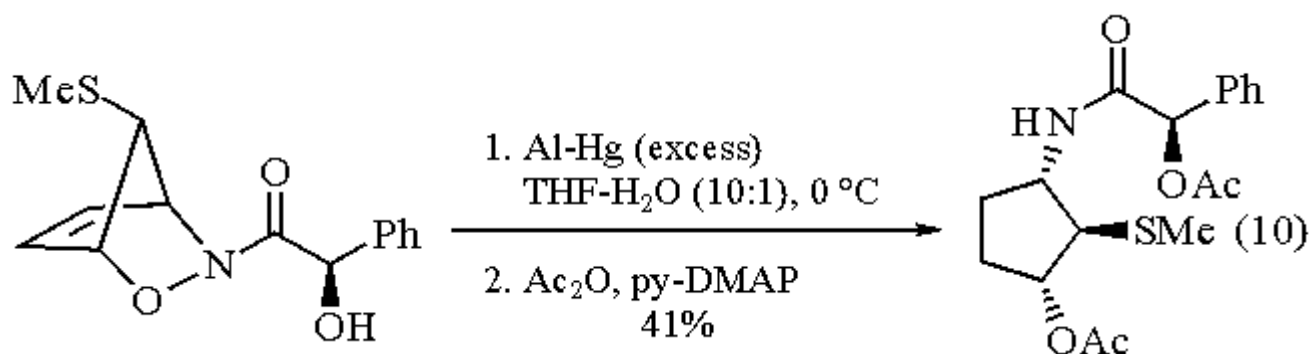
Ether linkages of various substrates, for example glycosides,²⁷ 1,3-dioxolanes,²⁸ tetrahydrofurans,^{29,30} and oxiranes,³¹ undergo reductive cleavage with formation of alcohols. Among the reactions listed, the reductive cleavage of epoxides (eq 9)^{32a} is presumably of the most importance. It has been widely used in the synthesis of prostaglandins,^{31a,b,32} steroids,^{31c,d} erythronolide B,³³ and vitamin precursors.³⁴



Deoxygenation of certain terpene oxides with Al foil activated by HgCl₂ has been reported instead of reduction to the desired alcohols.³⁵

N-O and N-N Bond Cleavage.

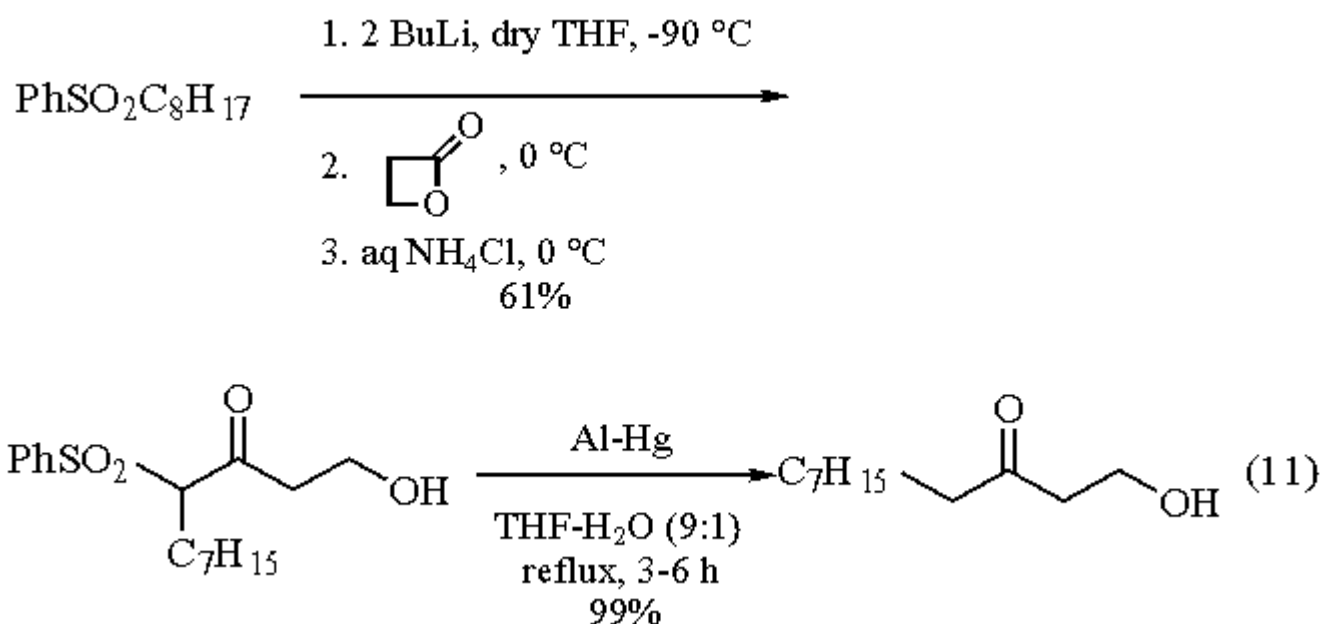
On exposure to excess Al-Hg in aqueous THF at 0 °C for several hours, N-O bonds in bicyclic Diels-Alder adducts are readily cleaved.³⁶ Mild conditions provide a highly chemoselective process and carbon-carbon double bonds and acid labile functional groups survive, in contrast to the alternative methods employed such as catalytic hydrogenolysis or reduction with *Zinc-Acetic Acid*.^{36a} The reaction occurs with high stereoselectivity and the product is formed with a *cis* disposition of N- and O-containing substituents (eq 10).³⁶



Aluminum amalgam is also highly effective in reductive cleavage of N-N bonds to produce amines.³⁷

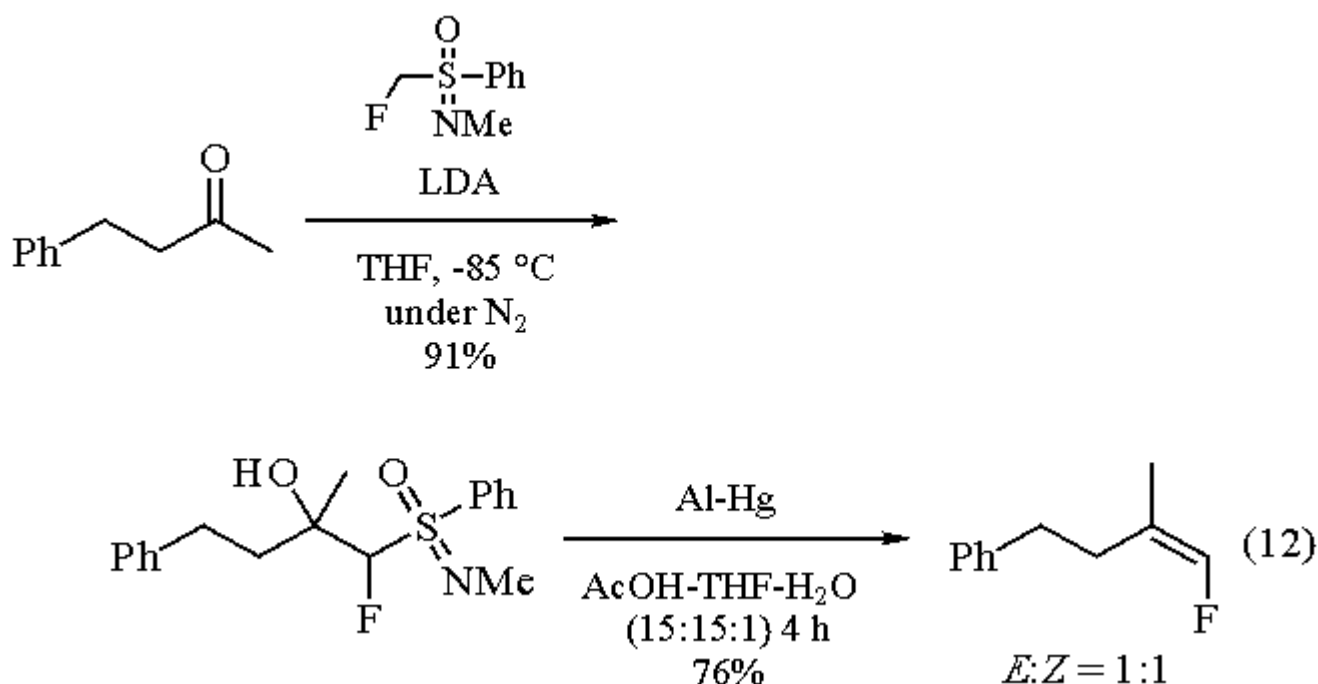
Reductive Desulfurization.

The ability of Al-Hg to reduce C-S bonds is widely used in organic synthesis in conjunction with methodology involving reactions of highly reactive α -sulfinyl- and α -sulfonylalkyl carbanions^{2b,38} as well as (α -sulfoximidoyl)alkyl carbanions.³⁹ Removal of the activating sulfur substituent is frequently accomplished using Al-Hg. The methodology offers facile synthetic approaches to ketones,^{2b,38,40} enones,⁴¹ di- and triketones,^{40,42} hydroxy ketones (eq 11),⁴³ unsaturated acids,⁴⁴ and γ -oxo- α -amino acids.⁴⁵



Readily removed on treatment with Al-Hg asymmetric sulfinyl and sulfonimidoyl groups may serve as chiral auxiliaries in enantiocontrolled synthesis of 3-substituted cycloalkanones⁴⁶ and 3-hydroxy⁴⁷ and 3-arylcarboxylic acid esters.⁴⁸

Aluminum amalgam mediated cleavage of C-S bonds plays an important role in sulfoximine-based alkenation of carbonyl compounds via β -hydroxysulfoximines⁴⁹ (eq 12).^{49b}



Aluminum amalgam can also be employed in reductive elimination of phenylthio groups from 2-phenylthioalkanones,⁵⁰ stereospecific reduction of sulfoximines,⁵¹ selective cleavage of the sulfinyl sulfur-methylene carbon bond in the presence of a disulfide moiety,⁵² and reductive scission of S-S and S-N bonds.^{53,54}

For some reactions mediated by aluminum activated with mercury(II) chloride, also see *Aluminum*.

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